

Galactic membership of BL Her type variable stars

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Abstract. As the RR Lyrae stars evolve on the Hertzsprung-Russell diagram they are believed to become short period Type II Cepheids, known as BL Her type (with a pulsation period from 1 to 3 – 8 days). Assuming that their mass is around $0.5 - 0.6 M_{\odot}$, and that they are low metallicity objects, they were thought to belong to the halo of the Milky Way. We investigated seven Galactic short period Type II Cepheids (BL Her, SW Tau, V553 Cen, DQ And, BD Cas, V383 Cyg, and KT Com) in order to establish their membership within the Galactic structure using the kinematic approach. *Gaia* should provide us with more data needed to conduct the study of the whole sample.

1. Introduction

The evolution of low mass stars, such as RR Lyrae, can be followed up in the Type II Cepheids. Wallerstein (2002) gives an overview of Type II Cepheids (T2C). The papers by Harris (1984, 1985) discuss the classification of T2Cs according to their distances from the Galactic plane, while the papers by Diethelm (1986, 1990) address the question of the relation of the metallicities and the position of these stars. By investigating the Galactic membership based on the kinematic approach we are able to reconstruct (within the limits of the model) the movement of an individual star in the Galaxy, which helps us to answer the question of the origin of metal-rich Type II Cepheids. The General Catalogue of Variable Stars¹ (GCVS) in 2012 contained 71 short period T2Cs, which were expanded in the time that has passed, but we stick to that sample, because they were relatively bright objects for which there was a chance to find all the data we needed (the distance or parallax, proper motion, and radial velocity).

2. Method

There are a few approaches for indicating the membership of stars of the Galactic components. Here, we shall use the kinematic approach. We start by converting the distance and position on the sky to the Galactocentric Cartesian system of Galactic coordinates (X, Y, Z). For this we use the well-known formulas:

¹<http://www.sai.msu.su/gcvs/gcvs/>

$$\begin{aligned}
X &= D \cos b \cos l - R_{\odot} \\
Y &= D \cos b \sin l \\
Z &= D \sin b
\end{aligned}
\tag{1}$$

In order to obtain the 3-D position vector and velocity vector of a star in space one needs the following data: two celestial coordinates, distance, two proper-motion components, and the radial velocity. Since these are pulsating variable stars they change their radial velocity due to pulsation too, so that one should be cautious when applying the radial velocity values.

In our original sample these necessary data were not available for all stars. For some stars we do not have the parallax or radial velocity, or both. All the data necessary for calculating the velocity components are available for seven stars in total. All the input data should be transformed into the heliocentric Cartesian system; for this purpose we use the procedure described in Johnson & Soderblom (1987). Then we correct velocity values for the solar motion. The obtained velocity components U, V, W are with respect to the local standard of rest (LSR).

The magnitude of the LSR velocity v ,

$$v = \sqrt{U_{\text{LSR}}^2 + V_{\text{LSR}}^2 + W_{\text{LSR}}^2} \tag{2}$$

is indicative of the star membership, to the thin disc, thick disc, or halo. If for a star the magnitude of the LSR velocity is very high (say, exceeds 250 km s^{-1}), then the probability that this star belongs to the thin or thick disc is very low. If it exceeds, say 100 km s^{-1} , then only the probability of belonging to the thin disc is very low.

3. Results

The stars which had all the required data are listed in Table 1.

Table 1. Stars examined for their Galactic membership (in the order of increasing period).

Name	RA (J2000) [h : m : s]	Dec (J2000) [° : ' : '']	Proper motion [mas/yr]	Radial velocity [km/s]	Parallax [mas]
BL Her	18:01:09.22	+19:14:56.68	−2.94	18.0	1.27
SW Tau	04:24:32.97	+04:07:24.05	4.05	10.9	2.8
V553 Cen	14:46:33.63	−32:10:15.25	5.01	−6.00	1.84
DQ And	00:59:34.47	+45:24:24.22	5.16	−230.91	0.67
BD Cas	00:09:51.39	+61:30:50.54	−1.1	−49.30	2.13
V383 Cyg	20:28:58.15	+34:08:06.36	−1.99	−24.4	4.44
KT Com	13:33:50.22	+17:25:30.37	−15.93	−13.0	5.50

Note: All the data were collected from: <http://simbad.u-strasbg.fr/simbad/>, and from the references within van Leeuwen (2002) for the Hipparcos data.

Figures 1 and 2 show the cross-section of the path of each stars in our sample in the past 12 Gyrs from the model calculations. All the stars in Figure 1 are members of the thin disc. DQ Andromedae (see Figure 2) is a halo star, but with a mean metallicity of $[\text{Fe}/\text{H}] = -0.17$ (Schmidt et al. 2011). Since the distances to almost all the stars are probably not precise enough, the results could change, but not too much.

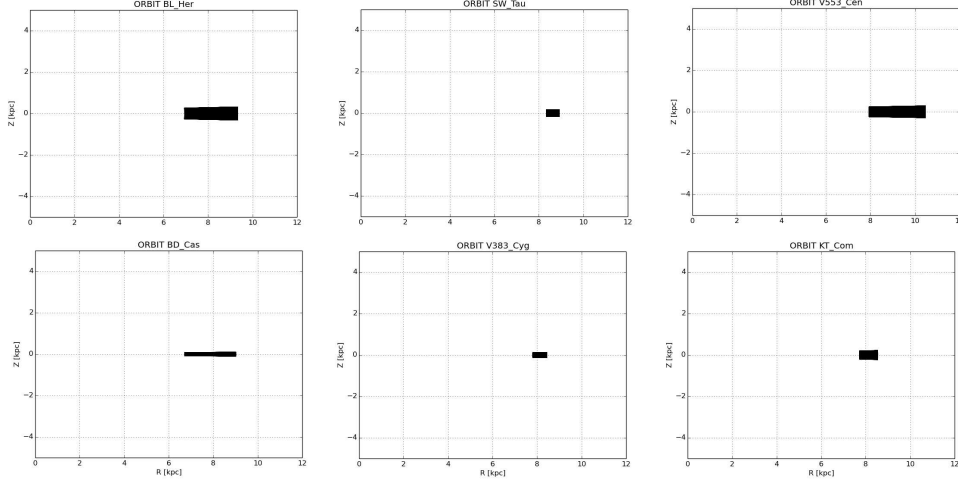


Figure 1. The meridional plots of star orbits for: BL Her, SW Tau, V553 Cen, BD Cas, V383 Cyg and KT Com in the order of their increasing periods. R is the distance from the Galactic rotation axis, z is the distance from the Galactic plane.

The Toomre diagram in Figure 3 shows the distribution of the examined stars in the calculated velocity planes. The lines show the approximate limits between the subsystems in the Galaxy: the innermost part being the thin disc, then the thick disc, and finally the halo.

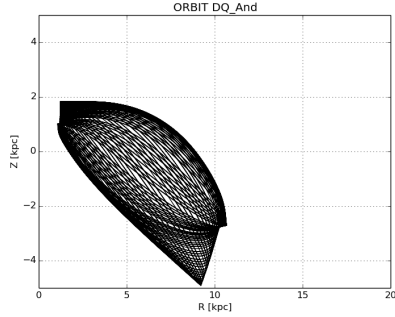


Figure 2. The meridional plot of DQ And. R and z are the same as in Figure 1.

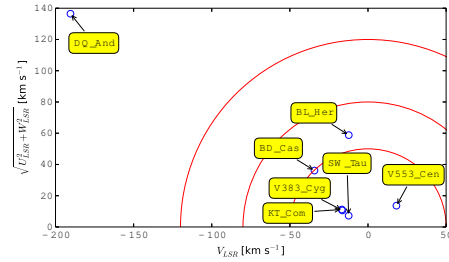


Figure 3. The Toomre diagram of the examined stars.

4. Conclusion

Out of the 71 stars we have studied, only 7 had enough data available to be examined in our model. Even though we are aware of a substantial error influence in the input data, we are still comfortable with stating that the model results do give us the Galactic membership of the stars.

Kinematically BL Her, SW Tau, V553 Cen, BD Cas, V383 Cyg, and KT Com could be thin disk stars, but by examining their light curve shapes it might happen that they turn out to be some other type of variable stars, not Type II Cepheids.

DQ And is the only star which shows evidence of being a member of the halo of the Milky Way, but the asymmetry of its calculated orbit is peculiar. If we consider that the Milky Way has experienced collisions with neighbouring dwarf galaxies, this asymmetry could be due to the capture of this star by our Galaxy or its motion around the centre of the Milky Way might have been perturbed.

In the following years the astrometric measurements from the *Gaia* satellite should give us much more insight into the understanding of the Galactic membership of Type II Cepheids.

Acknowledgements

The authors thank for the financial support from the Ministry of Education, Science and Technological Development of the Republic of Serbia through the projects 176004 and 176011 and the Hungarian National Research, Development and Innovation Office through NKFIH K-115709. This research has made use of NASA's Astrophysics Data System. This research has made use of the VizieR catalogue access tool, CDS, Strasbourg, France. The original description of the VizieR service was published in Ochsenbein et al. (2000).

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